Pipe Roofing Installation by Micro Tunneling Method

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ABSTRACT

This article described the process of installing the pipe roofing structure for Maluri underground KVMRT station Entrance A. The pipe roof was constructed using 780mm diameter steel pipes of 10mm thickness, installed via pipe jacking method using a Micro Tunnel Boring Machine (MTBM). The use of a separation plant for slurry treatment was suitable, given the site conditions and greatly improved productivity of the pipe jacking machine in the silty ground condition. The journal described why a pipe roof structure was needed and how it was constructed. The various safety measures and precautions taken were also covered herewith.

The southern most KVMRT underground station, Maluri Station, is located under busy Jalan Cheras. It has 4 entrances: Entrance A to cater to customers going to Aeon Maluri, Entrance B leading to the housing estate, Entrance C to allow for passenger connection between the KVMRT line and the existing Ampang STAR line and Entrance D for the park and ride service located adjacent to the station.

Of all the entrances, the construction of Entrance A posed the greatest challenge. This was due to the existence of utilities buried under that section of Jalan Cheras between Entrance A and the Maluri station box. These included telco lines, a 600mm SYABAS water pipe, and most importantly, 275 kV Tenaga Nasional Berhad (TNB) high voltage electrical cables. The electrical cables served as the main source of supply to the Bukit Bintang region.

Due to these constraints, a different construction approach was required, one that would not affect the utilities and the live traffic during the construction of the adit tunnel for Entrance A.

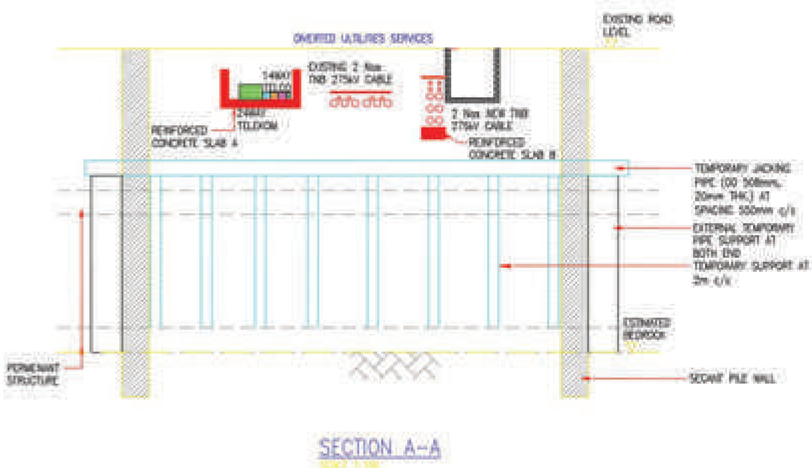

Figure 1: Cross-sectional view of pipe roofing structure

METHOD

Given the complexity of the required works, a special technique was needed to provide the fastest and safest solution. A series of pipes installed next to one another to form a pre-support structure, called a pipe roof, was applied at site. The pipe roof structure was designed using 17 steel pipes of 780mm outer diameter with 10mm wall thickness. The completed length of each pipe would be 17.5m long, with 13m of the pipe underground and the remainder protruding equally at both ends. Eleven metres of tunnelling were required for one pipe installation. Due to the size of the jacking frame, 6m-long steel pipes were used. To complete one installation, three 6m-long steel pipes were required.

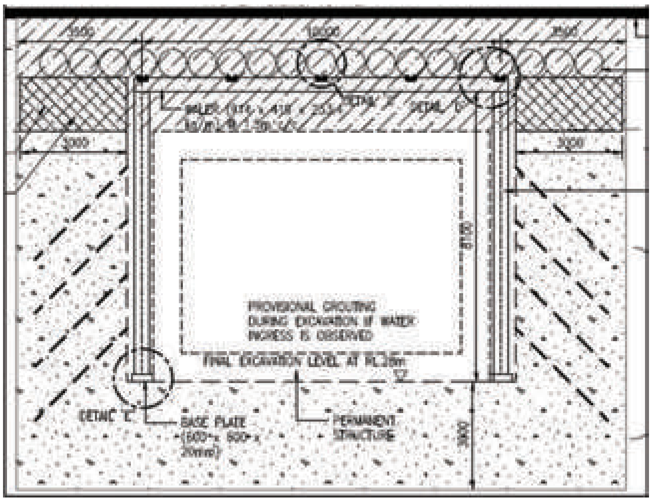

Figure 2: Tunnel adit structure under installed pipe roof

The pipe roofing structure would provide a safe working environment for the excavation to be carried out underneath it. In addition to the installed pipes, permeation grouting was carried out between the installed pipes to further consolidate the ground and reduce water seepage during excavation.

MINING EQUIPMENT

To install the 780mm diameter steel pipes, a Herrenknecht AVN500XC pipe jacking machine was used. The pipe jacking machine, coupled with an extension kit, had an external diameter of 800mm. Attached to the front of the pipe jacking machine was a rock cutting head of 826mm in diameter to allow for overcut. This clearance allowed the machine to steer and correct its alignment throughout the drive. The tolerance of the alignment was capped at 25mm in each direction, reducing the chance of pipe damage. A launch and retrieval shaft had to be constructed to facilitate the launching and retrieval of the machine. During the advancement of the pipes, bentonite was pumped to the external surface of the pipe via 1-inch ports installed inside the 6m length pipes.

This served to lubricate and reduce frictional force of the pipe against the ground and to provide support to the ground in order to prevent settlement. After completing each drive, the annulus gap between the ground and the pipes would be filled with cement grout to avoid ground settlement.

Table 1: Technical Details of Micro Tunnel Boring Machine

Description	Value	Unit
Machine Outer Can Diameter	800	mm
Cutter Head Outer Diameter	826	mm
Overall Length with Trailing Can	5400	mm
Number of Drive Motors	3	Pcs
Max Cutterhead Torque	22.2	KNm
Number of Steering Cylinders	3	Pcs
Max Steering Angle	4.2	°
Number of Jacking Cylinders	2	Pcs
Jacking Cylinder Stroke	4000	mm
Max Jacking Force per Cylinder	3500	kN

Table 2: Mungo separation plant technical details

Description	Value	Unit
Pump Driving Motor	18.5	kW
Classifying Screen Size	2.5	mm
Dewatering Screen Size	0.5	mm
Slurry Volume Capacity	150	m^3/h
Solids Capacity	30	t/h
Max Grain Size	50	mm

The excavated material was removed from the front of the cutterhead via a slurry circuit, which was channelled to a separation plant for processing. The separation plant used was a Schauenburg Mungo slurry treatment plant, which featured a single hydrocyclone stage and 2 separate screens, with the finer screen having 0.5mm slit. The plant was used in conjunction with the Microtunnel Boring Machine (MTBM) to clean and recycle the slurry, thereby increasing its service life. From the station box excavation, it was known that the area around the station box comprised backfilled material that was mainly sandy and silty clay.

WORK SEQUENCE

Prior to commencing installation of the pipes, a working platform was fabricated to achieve the desired axis of the pipes. Once completed, the same work process was repeated 16 times to install each individual pipe. The work process can be summarised as follows:

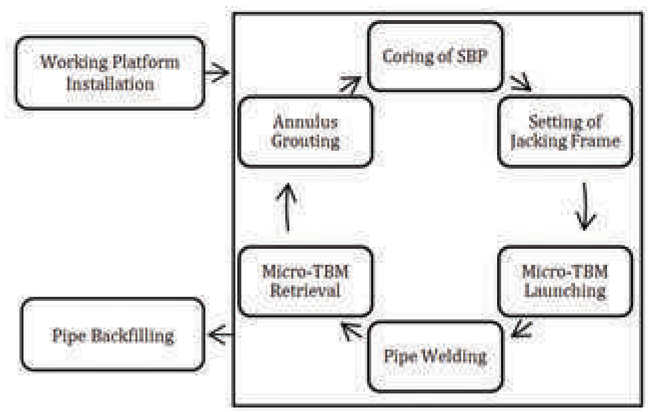

Figure 3: Pipe roof installation sequence

As the cutterhead of the pipe jacking machine could not cut through the steel reinforcement bars of the Secant Bored Piles (SBP), coring had to be done to allow direct access of the machine into the ground.

To set up, the jacking frame was positioned with the help of surveyors. The alignment of the jacking frame and the navigation laser was set before the MTBM could be lowered into the shaft onto the jacking frame. To transfer the jacking force to the SBP, a fixture called a thrust spacer was fabricated and placed between the jacking frame and the SBP. Any remaining space between the thrust spacer and the SBP was filled with non-shrink grout to provide an even surface contact area.

Figure 4: 24 cores to complete stitch coring of secant bored pile

After completing the setup of the machine, a launch seal with a rubber gasket was attached to the launch face. This launch seal would prevent the circulating slurry from leaking out of the cored hole into the jacking pit. By retaining the slurry within the ground, the face pressure of the ground could be maintained, reducing the possibility of a sinkhole formation. A rubber sheet of a suitable Shore hardness and elasticity was selected to allow deformation without failure when the MTBM entered the cored hole.

Figure 5: The setup of the jacking frame had to be done for each individual drive

During a drive, the machine face pressure was capped at 0.35 bars to balance the earth pressure, where the overburden is 3.1m. Throughout the drive, the cutterhead torque was maintained at 130kNm-150kNm to prevent dipping of the machine in the soft clay ground. A jacking force of about 190kN-240kN was maintained, which resulted in an average jacking speed of 150mm/min. The jacking speed was highly dependent on the ground condition at the location of excavation. A summary is as follows:

Table 3: MTBM mining parameters

Parameters	Value	Unit
Face Pressure	0.35	Bar
Cutterhead Torque	130 - 150	kNm
Cutterhead Speed	10 - 13	Rpm
Jacking Force	190 - 240	kN
Average Jacking Speed	150	mm/min

Figure 6: Left: Installed launch shield with rubber gasket; Right: MTBM being launched in the cored SBP

Figure 8: Left: Breakthrough of MTBM at retrieval shaft; Right: Opening for disconnection of umbilical hoses and slurry lines

After the full length of the machine had entered the cored SBP, the jacking cylinders were retracted and a 6m length steel pipe was lowered onto the jacking frame. The trailing edge of the machine and the leading edge of the new pipe were clamped using a clamping fixture to be tack welded.

The fixture was removed for complete welding of the full circumference of the pipe machine connection. The welding was done using a Metal Inert Gas (MIG) welding machine. The MIG machine was used for a number of reasons:

a) Faster welds to reduce time wastage.
b) Low skill factor for operator.
c) Better welds as flux was not used.

Three lengths of 780mm outer diameter steel pipes were joined by welding the pipes subsequently, one after another. After each weld, the quality was checked by the supervisor using Dye Penetrant Inspection (DPI).

At the retrieval shaft, a fixture was fabricated to facilitate the retrieval of the MTBM. The fixture allowed the MTBM to slide out onto the fixture. When the full length of the MTBM had exited the ground, an opening was cut into the side of the steel pipe which would allow the disconnection of the umbilical cables and slurry lines to the MTBM. The MTBM could only be retrieved from the shaft after all hoses and pipes were disconnected. The MTBM was placed on a lorry and transported back to the launch shaft for relaunching. This process was repeated for each drive.

After completing each drive, the annulus gap between the SBP and the pipe was sealed with concrete. Annulus grouting was then done via the same bentonite ports to displace the bentonite injected during the drive and to consolidate the soil around the newly-installed pipe to prevent settlement. At least 2 passes of annulus grouting were carried out on each pipe.

Backfilling of the pipe was done only after all pipes had been installed. Backfilling was done using cement grout of water cement in the ratio of 2:1. Both ends of the steel pipe were sealed using steel plates to form end caps. On the launch site end cap, an entry port was fabricated to allow for the administering of the grout. At the retrieval site, a bleed valve was attached to bleed air while pumping grout from the launch site. This pumpable grout was hand mixed on site before pumping.

Figure 7: Left: Clamping fixture to ensure concentricity of pipes before welding; Right: DPI testing on completed welds

Figure 9: Top: Sealing of the annulus gap between the SBP and the pipe using concrete; One-inch ports inside the pipe used to inject bentonite during excavation and annulus grouting

Figure 10: Steel plates were used as end caps for the pipe. Grout was pumped via 2 inch ports welded to the top of the end caps

CONTINGENCY PLAN

A contingency plan was devised to ensure that any situation resulting from the pipe jacking operation could be contained quickly. The plan included:

a) Settlement monitoring of Jalan Cheras.
b) A dedicated Bull Gang.

As shown in the layout below, 18 settlement markers were installed in Jalan Cheras. During pipe jacking, settlement data was taken hourly, using high precision monitoring equipment that was accurate to 1mm. At other times, the settlement data was taken at 4-hour intervals.

At the time of writing, the maximum settlement was 17mm depression, concentrated at the mid span of the pipe roofing structure.

A full-time Bull Gang was stationed at the site to visually monitor the busy road surface and to immediately respond in the case of an incident arising from the pipe jacking operation. Its members would have access to plastic road barriers and traffic flags to divert traffic away from the affected area.

CONCLUSION

The construction of the pipe roofing at Maluri Station proved to be a delicate and challenging task. The highly unpredictable ground condition further complicated the operation. Two strong shifts with the drive to succeed, were of paramount importance in order to deliver the project ahead of schedule while being incident free.

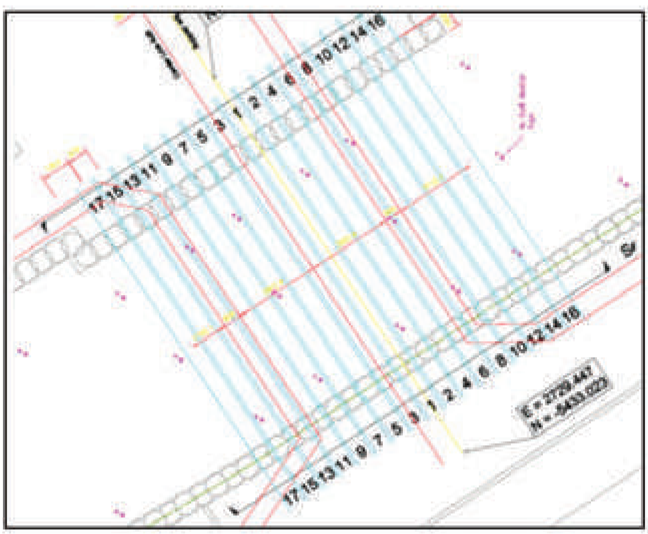

Figure 11: Position of 18 settlement markers along Jalan Cheras

It was found that the backfilling of the pipes should be done after all pipes were complete installed. This allowed for the annulus grouting of the pipe to be done to ensure that the ground around the pipes was consolidated before infilling of grout.

The use of a separation plant was vital especially in an enclosed and isolated urban site such as Maluri Station Entrance A. The separation plant allowed the circulation slurry to be cleaned and recycled. Larger material such as wood and pebbles could be removed easily, while the hydrocyclone allowed finer material to be disposed. This increased the service life of slurry and preveneds material build-up within the storage tank.

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